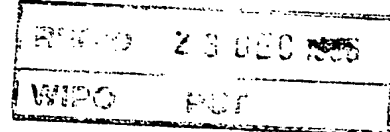


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Coated milling insert

The present invention relates to a coated cutting tool (cemented carbide insert) particularly useful for wet and dry milling of low and medium alloyed steels, with raw surfaces such as cast skin, forged skin, hot or cold rolled skin or pre-machined surfaces.

When milling low and medium alloyed steels with cemented carbide tools the cutting edge is worn according to different wear mechanisms, such as chemical wear, abrasive wear, adhesive wear and by edge chipping caused by cracks formed along the cutting edge, the so called comb cracks.

The comb crack formation is particularly severe when wet milling is employed (using coolant). Coolant and work piece material may penetrate and widen the comb cracks and the edge will start to chip. A chipped edge will generate a bad surface finish of the machined component.

Different cutting conditions require different properties of the cutting insert. For example, when cutting in steels with raw surface zones a coated cemented carbide insert must consist of a tough carbide and have very good coating adhesion. When milling in low alloyed steels the adhesive wear is generally the dominating wear type. Here preferably thin (1-3  $\mu\text{m}$ ) CVD- or PVD-coatings have to be used.

Measures can be taken to improve the cutting performance with respect to a specific wear type. However, very often such action will have a negative effect on other wear properties.

The influence of some possible measures is given below:

1.) Comb crack formation can be reduced by lowering the binder phase content. However, such action will lower the toughness properties of the cutting inserts which is not desirable.

2.) Improved abrasive wear can be obtained by increasing the coating thickness. However, thick coatings increase the risk for flaking and will lower the resistance to adhesive wear.

3.) Milling at high cutting speeds and at high cutting edge temperatures requires a cemented carbide with a rather high amount of cubic carbides (solid solution of WC-TiC-TaC-NbC). Such carbides will more easily develop comb cracks.

So far it has been very difficult to improve all tool properties simultaneously. Commercial cemented carbide grades have therefore been optimized with respect to one or few of these wear types and hence to specific application areas.

Swedish patent application 9501286-0 discloses a coated cutting insert particularly useful for dry milling of grey cast iron. The insert is characterized by a straight WC-Co cemented carbide grade and a coating including a layer of  $TiC_xN_yO_z$  with columnar grains and a top layer of fine grained textured  $\alpha-Al_2O_3$ .

Swedish patent application 9502640-7 discloses a coated turning insert particularly useful for intermittent turning in low alloyed steel. The insert is characterized by a WC-Co cemented carbide body having a highly W-alloyed Co-binder phase and a coating including a layer of  $TiC_xN_yO_z$  with columnar grains and a top layer of a fine grained, textured  $\alpha-Al_2O_3$ .

Swedish patent application 9503056-5 discloses a coated turning cutting tool particularly useful for cutting in hot and cold forged low alloyed steel. The insert is characterized by a WC-Co cemented carbide body having a highly W-alloyed Co-binder phase and a coating including a layer of  $TiC_xN_yO_z$  with columnar grains and a top layer of a fine-grained,  $\alpha-Al_2O_3$ .

It has now surprisingly been found that by combining many different features a cutting tool for milling with excellent cutting performance in low and medium alloyed steel with or without raw surface zones both in wet and dry milling can be obtained. The cutting tool according to the invention shows improved properties with respect to many of the wear types earlier mentioned.

The milling cutting insert according to the invention consists of: a cemented carbide body with a highly W-alloyed binder phase and with a well balanced chemical composition and grain size of the WC, a columnar  $TiC_xN_yO_z$ -layer, a  $\kappa-Al_2O_3$ -layer, a TiN-layer and optionally followed by smoothening the cutting edges by brushing the edges with e.g. a SiC based brush.

Fig 1 is a micrograph in 10000 X magnification of a coated insert according to the present invention in which

- A - cemented carbide body
- B -  $TiC_xN_yO_z$ -layer with equiaxed grains
- C -  $TiC_xN_yO_z$ -layer with columnar grains

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D -  $\alpha$ - $\text{Al}_2\text{O}_3$ -layer with columnar like grains

E - TiN-layer preferred, could be an option

According to the present invention a milling tool insert is provided with a cemented carbide body with a composition of 8.6-9.5 wt% Co, preferably 8.7-9.5 wt% Co, most preferably 8.8-9.4 wt% Co, 0.2-1.8 wt% cubic carbides, preferably 0.4-1.8 wt% cubic carbides, most preferably 0.5-1.7 wt% cubic carbides of the metals Ta, Nb and Ti and balance WC. The cemented carbide may also contain other carbides from elements from group IVb, Vb or VIb of the periodic table. The content of Ti is preferably on a level corresponding to a technical impurity. The average grain size of the WC is in the range of about 1.5-2  $\mu\text{m}$ , preferably about 1.7  $\mu\text{m}$ .

The cobalt binder phase is highly alloyed with W. The content of W in the binder phase can be expressed as the CW-ratio =  $M_s / (\text{wt\% Co} \cdot 0.0161)$ , where  $M_s$  is the measured saturation magnetization of the cemented carbide body and wt% Co is the weight percentage of Co in the cemented carbide. The CW-value is a function of the W content in the Co binder phase. A low CW-value corresponds to a high W-content in the binder phase.

It has now been found according to the present invention that improved cutting performance is achieved if the cemented carbide body has a CW-ratio of 0.78-0.93, preferably 0.80-0.91, and most preferably 0.82-0.90. The cemented carbide may contain small amounts, < 1 volume %, of  $\eta$ -phase ( $\text{M}_6\text{C}$ ), without any detrimental effect. From the CW-value it follows that no free graphite is allowed in the cemented carbide body according to the present invention.

The cemented carbide body may contain a thin (about 5-25  $\mu\text{m}$ ) surface zone depleted in cubic carbides and often enriched in binder phase according to prior art such as disclosed in US 4,610,931. In this case the cemented carbide may contain carbo-nitride or even nitride.

The coating comprises

- a first (innermost) layer of  $\text{TiC}_x\text{N}_y\text{O}_z$  with  $x+y+z=1$ , preferably  $z < 0.5$ , with equiaxed grains with size < 0.5  $\mu\text{m}$  and a total thickness < 1.5  $\mu\text{m}$  and preferably > 0.1  $\mu\text{m}$ .

- a layer of  $\text{TiC}_x\text{N}_y\text{O}_z$  with  $x+y+z=1$ , preferably with  $z=0$  and  $x > 0.3$  and  $y > 0.3$ , with a thickness of 1-6  $\mu\text{m}$ , preferably 2-5  $\mu\text{m}$ ,

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with columnar grains and with an average diameter of about  $<5 \mu\text{m}$ , preferably  $0.1-2 \mu\text{m}$

- a layer of a smooth, fine-grained (grain size about  $0.5-2 \mu\text{m}$ )  $\text{Al}_2\text{O}_3$  consisting essentially of the  $\kappa$ -phase. However, the layer may contain small amounts, 1-3 vol-%, of the  $\theta$ - or the  $\alpha$ -phases as determined by XRD-measurement. The  $\text{Al}_2\text{O}_3$ -layer has a thickness of  $0.5-5 \mu\text{m}$ , preferably  $0.5-2 \mu\text{m}$ , and most preferably  $0.5-1.5 \mu\text{m}$ . Preferably, this  $\text{Al}_2\text{O}_3$ -layer is followed by a further layer ( $<1 \mu\text{m}$ , preferably  $0.1-0.5 \mu\text{m}$  thick) of  $\text{TiN}$ , but the  $\text{Al}_2\text{O}_3$  layer can be the outermost layer. This outermost layer,  $\text{Al}_2\text{O}_3$  or  $\text{TiN}$ , has a surface roughness  $R_{\text{max}} \leq 0.4 \mu\text{m}$  over a length of  $10 \mu\text{m}$ . The  $\text{TiN}$ -layer, if present, is preferably removed along the cutting edge.

According to the method of the invention a WC-Co-based cemented carbide body is made with a highly W-alloyed binder phase with a CW-ratio according to above and a content of cubic carbide according to above and a WC grain size according to above and preferably without a binder phase enriched surface zone, a first (innermost) layer of  $\text{TiC}_x\text{N}_y\text{O}_z$  with  $x+y+z=1$ , preferably  $z < 0.5$ , with a thickness of  $< 1.5 \mu\text{m}$ , and with equiaxed grains with size  $< 0.5 \mu\text{m}$  using known CVD-methods.

- a layer of  $\text{TiC}_x\text{N}_y\text{O}_z$   $x+y+z=1$ , preferably with  $z=0$  and  $x > 0.3$  and  $y > 0.3$ , with a thickness of  $1-6 \mu\text{m}$ , preferably  $2-5 \mu\text{m}$ , with columnar grains and with an average diameter of about  $<5 \mu\text{m}$ , preferably  $<2 \mu\text{m}$ , using preferably MTCVD-technique (using acetonitrile as the carbon and nitrogen source for forming the layer in the temperature range of  $700-900^\circ\text{C}$ ). The exact conditions, however, depend to a certain extent on the design of the equipment used.

- a smooth  $\text{Al}_2\text{O}_3$ -layer essentially consisting of  $\kappa$ - $\text{Al}_2\text{O}_3$  is deposited under conditions disclosed in e.g. EP-A-523 021. The  $\text{Al}_2\text{O}_3$  layer has a thickness of  $0.5-5 \mu\text{m}$ , preferably  $0.5-2 \mu\text{m}$ , and most preferably  $0.5-1.5 \mu\text{m}$ . Preferably, a further layer ( $<1 \mu\text{m}$ , preferably  $0.1-0.5 \mu\text{m}$  thick) of  $\text{TiN}$  is deposited, but the  $\text{Al}_2\text{O}_3$  layer can be the outermost layer. This outermost layer,  $\text{Al}_2\text{O}_3$  or  $\text{TiN}$ , has a surface roughness  $R_{\text{max}} \leq 0.4 \mu\text{m}$  over a length of  $10 \mu\text{m}$ . The smooth coating surface can be obtained by a gentle wet-blasting the coating surface with fine grained (400-150 mesh) alumina powder or by brushing (preferably used when  $\text{TiN}$  top coating is present) the edges with brushes based on e.g.  $\text{SiC}$  as disclosed e.g.

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in Swedish patent application 9402543-4. The TiN-layer, if present, is preferably removed along the cutting edge.

#### Example 1

5 A. A cemented carbide milling tool in accordance with the invention, inserts of style SEKN 1204 AZ with the composition 9.1 wt-% Co, 1.25 wt-% TaC, 0.30 wt-% NbC and balance WC, with a binder phase highly alloyed with W corresponding to a CW-ratio of 0.86 were coated with a 0.5  $\mu\text{m}$  equiaxed TiCN-layer (with a high  
10 nitrogen content corresponding to an estimated C/N-ratio of 0.05) followed by a 4  $\mu\text{m}$  thick TiCN-layer with columnar grains by using MTCVD-technique (temperature 885-850  $^{\circ}\text{C}$  and  $\text{CH}_3\text{CN}$  as the carbon/nitrogen source). In subsequent steps during the same coating cycle, a 1.0  $\mu\text{m}$  thick layer of  $\text{Al}_2\text{O}_3$  was deposited using a tem-  
15 perature 970  $^{\circ}\text{C}$  and a concentration of  $\text{H}_2\text{S}$  dopant of 0.4 % as disclosed in EP-A-523 021. A thin (0.3  $\mu\text{m}$ ) layer of TiN was deposited on top according to known CVD-technique. XRD-measurement showed that the  $\text{Al}_2\text{O}_3$ -layer consisted of 100 %  $\kappa$ -phase. The cemented carbide body had a WC grain size in average of 1.65  $\mu\text{m}$ . The coated  
20 inserts were brushed by a nylon straw brush containing SiC grains. Examination of the brushed inserts in a light microscope showed that the thin TiN-layer had been brushed away only along the cutting edge leaving there a smooth  $\text{Al}_2\text{O}_3$ -layer surface. Coating thickness measurements on cross sectioned brushed samples showed  
25 no reduction of the coating along the edge line except for the outer TiN-layer that was removed.

30 B. A strongly competitive cemented carbide grade in style SEKN 1204 from an external leading carbide producer was selected for comparison in a wet milling test. The carbide had a composition of 9.0 wt-% Co, 0.2 wt-% TiC, 0.5 wt-% TaC, 0.1 wt-% NbC balance WC and a CW-ratio of 0.95. The WC-grain size was 2.5  $\mu\text{m}$ . The insert had a coating consisting of a 6  $\mu\text{m}$  TiCN layer and a 0.3  $\mu\text{m}$  TiN layer.

35 Insert from A was compared against insert from B in a wet milling test in a medium alloyed steel (HB=310) with hot rolled surfaces. Two parallel bars each of a thickness of 35 mm were central positioned relatively the cutter body (diameter 100 mm), and the bars were placed with an air gap of 10 mm between them.

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The cutting data were:

Speed= 160 m/min,

Feed= 0.20 mm/rev

Cutting depth= 2 mm, single tooth milling with coolant.

5 A comparison was made after milling 1200 mm. Variant A according to the invention, showed no comb cracks and variant B showed 14 comb cracks. After milling 1800 mm variant B broke down due to a lot of chipping and fracture between the comb cracks. Variant A according to the invention lasted 4200 mm corresponding to an effective tool life of 11 min compared with about 4 min for variant B.

### Example 2

15 A. A cemented carbide milling tool in accordance with the invention, inserts of style SEKN 1204 AZ with the composition 9.1 wt-% Co, 1.23 wt-% TaC, 0.30 wt-% NbC and balance WC, with a binder phase highly alloyed with W corresponding to a CW-ratio of 0.85 were coated with a 0.5  $\mu\text{m}$  equiaxed TiCN-layer (with a high nitrogen content corresponding to an estimated C/N-ratio of 0.05) followed by a 3.7  $\mu\text{m}$  thick TiCN-layer with columnar grains by using MTCVD-technique (temperature 835-850 °C and  $\text{CH}_3\text{CN}$  as the carbon/nitrogen source). In subsequent steps during the same coating cycle, a 0.9  $\mu\text{m}$  thick layer of  $\text{Al}_2\text{O}_3$  was deposited using a temperature 970 °C and a concentration of  $\text{H}_2\text{S}$  dopant of 0.4 % as disclosed in EP-A-523 021. A thin (0.3  $\mu\text{m}$ ) layer of TiN was deposited on top according to known CVD-technique. XRD-measurement showed that the  $\text{Al}_2\text{O}_3$ -layer consisted of 100 %  $\kappa$ -phase. The cemented carbide body had a WC grain size in average of 1.6  $\mu\text{m}$ .

30 B. A strongly competitive cemented carbide grade in style SEKN 1204 from an external leading cemented carbide producer was selected for comparison in a wet milling test. The carbide had a composition of 11.0 wt-% Co, 0.2 wt-% TaC, 0.3 wt-% NbC balance WC and a CW-ratio of 0.90. The insert had a coating consisting of a 0.5  $\mu\text{m}$  equiaxed TiCN layer, 2.0  $\mu\text{m}$  TiCN columnar layer, 2.0  $\mu\text{m}$   $\kappa$ - $\text{Al}_2\text{O}_3$ -layer and a 0.3  $\mu\text{m}$  TiN-layer.

35 C. A strongly competitive cemented carbide grade in style SEKN 1204 from an external leading carbide producer. The carbide had a composition of 7.5 wt-% Co, 0.4 wt-% TaC, 0.1 wt-% NbC, 0.3 wt-% TiC

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balance WC and a CW-ratio of 0.95. The insert had a coating consisting of a 0.5  $\mu\text{m}$  equiaxed TiCN-layer, 2.1  $\mu\text{m}$  columnar TiCN-layer, 2.2  $\mu\text{m}$   $\kappa\text{-Al}_2\text{O}_3$ -layer and a 0.3  $\mu\text{m}$  TiN-layer.

Inserts from A were compared against inserts from B and C in a wet milling test in a low alloyed steel (HB=190) with hot rolled surfaces. The bars were as very common extremely rusty due to outdoor stocking. Two parallel bars each of a thickness of 32 mm were central positioned relatively the cutter body (diameter 100 mm), and the bars were placed with an air gap of 10 mm between them.

The cutting data were:

Speed= 150 m/min,

Feed= 0.20 mm/rev

Cutting depth= 2 mm, single tooth milling with coolant.

The insert C broke after 1100 mm, the insert B broke after 2150 mm and the insert A, according to the invention, broke after 2400 mm.

In this test all coatings were of similar type, and the major difference were on the cemented carbide. The results show that the coated cemented carbide according to the invention exhibited longer tool life than two important competitor grades containing less and more binder phase resp than the coated grade according to the invention.

### Example 3

A. A cemented carbide milling tool in accordance with the invention, inserts of style SERN 1204 AZ with the composition 9.1 wt-% Co, 1.23 wt-% TaC, 0.30 wt-% NbC and balance WC, with a binder phase highly alloyed with W corresponding to a CW-ratio of 0.86 were coated with a 0.5  $\mu\text{m}$  equiaxed TiCN-layer (with a high nitrogen content corresponding to an estimated C/N-ratio of 0.05) followed by a 3.7  $\mu\text{m}$  thick TiCN-layer with columnar grains by using MTCVD-technique (temperature 885-850  $^{\circ}\text{C}$  and  $\text{CH}_3\text{CN}$  as the carbon/nitrogen source). In subsequent steps during the same coating cycle, a 1.1  $\mu\text{m}$  thick layer of  $\text{Al}_2\text{O}_3$  was deposited using a temperature of 970  $^{\circ}\text{C}$  and a concentration of  $\text{H}_2\text{S}$  dopant of 0.4 % as disclosed in EP-A-523 021. A thin (0.3  $\mu\text{m}$ ) layer of TiN was deposited on top according to known CVD-technique. XRD-measurement showed that the  $\text{Al}_2\text{O}_3$ -layer consisted of 100 %  $\kappa$ -phase. The ce-



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mented carbide body had a WC grain size in average of 1.7  $\mu\text{m}$ . The coated inserts were brushed by a nylon straw brush containing SiC grains. Examination of the brushed inserts in a light microscope showed that the thin TiN-layer had been brushed away only along the cutting edge leaving there a smooth  $\text{Al}_2\text{O}_3$ -layer surface. Coating thickness measurements on cross sectioned brushed samples showed no reduction of the coating along the edge line except for the outer TiN-layer that was removed.

B. A strongly competitive cemented carbide grade in style SEKN 1204 from an external leading carbide producer. The carbide had a composition of 8.0 wt-% Co, 1.9 wt-% TaC, 0.2 wt-% NbC, 0.2 wt-% TiC balance WC and a CW-ratio of 0.85. The insert had a coating consisting of a 1.1  $\mu\text{m}$  TiN layer and 3.3  $\mu\text{m}$  TiC layer.

C. A strongly competitive cemented carbide grade in style SEKN 1204 from an external leading carbide producer. The carbide had a composition of 10.0 wt-% Co, 2.0 wt-% TaC, 0.2 wt-% TiC, balance WC and a CW-ratio of 0.90. The insert had a coating consisting of a 0.5  $\mu\text{m}$  equiaxed TiCN layer, 3.3  $\mu\text{m}$  TiCN columnar layer, 0.7  $\mu\text{m}$   $\text{K-Al}_2\text{O}_3$ -layer and a 0.5  $\mu\text{m}$  TiN layer.

Inserts from A was compared against inserts from B and C in a dry milling test in a low alloyed steel (HB=290) with pre machined surfaces. A bar with a thickness of 180 mm were central positioned relatively the cutter body (diameter 250 mm)

The cutting data were:

Speed= 204 m/min,

Feed= 0.22 mm/rev

Cutting depth= 2 mm, single tooth milling dry conditions.

Insert B broke after 5000 mm after comb crack formation and chipping. Insert C broke after 5400 mm by similar wear pattern and insert A was stopped after 6000 mm without other visible wear than a few small comb cracks.

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Claims

1. A cutting tool insert for milling low and medium alloyed steels with or without raw surfaces during wet or dry conditions comprising a cemented carbide body and a coating

characterized in that said cemented carbide body comprises WC, 8.6-9.5 wt-% Co and 0.2-1.8 wt-% cubic carbides of Ta, Ti and Nb, with Ti present on a level corresponding to a technical impurity, and a highly W-alloyed binder phase with a CW-ratio of 0.78-0.93 and in that said coating comprises

- a first (innermost) layer of  $TiC_xN_yO_z$  with  $x+y+z=1$ , preferably  $z<0.5$ , with a thickness of 0.1-1.5  $\mu m$ , and with equiaxed grains with size  $<0.5 \mu m$

- a layer of  $TiC_xN_yO_z$  with  $x+y+z=1$ , preferably with  $z=0$  and  $x>0.3$  and  $y>0.3$ , with a thickness of 1-6  $\mu m$  with columnar grains with a diameter of about  $<5 \mu m$

- a layer of a smooth, fine-grained (0.5-2  $\mu m$ )  $\kappa-Al_2O_3$  with a thickness of 0.5-5  $\mu m$  and

- preferably an outer layer of TiN with a thickness of  $<1 \mu m$ .

2. Milling insert according to claim 1

characterized in that the cemented carbide has the composition 8.8-9.4 wt-% Co and 0.4-1.8 wt% carbides of Ta and Nb.

3. Milling insert according to any of the preceding claims characterized in a CW-ratio of 0.82-0.90.

4. Milling insert according to any of the preceding claims

characterized in that the outermost TiN-layer, if present, has been removed along the cutting edge.

5. Method of making a milling insert comprising a cemented carbide body and a coating characterized in that WC-Co-based cemented carbide body with a highly W-alloyed binder phase with a CW-ratio of 0.78-0.93 is coated with

- a first (innermost) layer of  $TiC_xN_yO_z$  with  $x+y+z=1$ , preferably  $z<0.5$ , with a thickness of 0.1-1.5  $\mu m$ , with equiaxed grains with size  $<0.5 \mu m$  using known CVD-methods

- a layer of  $TiC_xN_yO_z$  with  $x+y+z=1$ , preferably with  $z=0$  and  $x>0.3$  and  $y>0.3$ , with a thickness of 1-6  $\mu m$  with columnar grains with a diameter of about  $<5 \mu m$  deposited by MTCVD-technique, using acetonitrile as the carbon and nitrogen source for forming the layer in a preferred temperature range of 850-900 °C.

- a layer of a smooth  $K-Al_2O_3$  with a thickness of 0.5-5  $\mu m$  and
- preferably a layer of TiN with a thickness of  $<1 \mu m$ .

6. Method according to the previous claim characterized in that said cemented carbide body has a cobalt content of 8.8-9.4 wt% and 0.4-1.8 wt% cubic carbides of Ta and Nb.

7. Method according to any of the claims 5 and 6 characterized in a CW-ratio of 0.82-0.90.

8. Method according to any of the claims 5, 6 and 7 characterized in that the outermost TiN-layer, if present, is removed along the cutting edge.

Abstract

The present invention discloses a coated milling insert particularly useful for milling in low and medium alloyed steels with or without raw surface zones during wet or dry conditions. The insert is characterized by WC-Co cemented carbide with a low content of cubic carbides and a highly W-alloyed binder phase and a coating including an innermost layer of  $TiC_xN_yO_z$  with columnar grains and a top layer of TiN and an inner layer of  $\alpha-Al_2O_3$ .

